4-218C

BIBLIOGRAPHIC DATA SHEET	1. Report No. APTD-1129	2.	PB 210 678
4. Title and Subtitle: National Inventory of Sources and Emissions Barium, Boron, Copper, Selenium, and Zinc 1969 - Copper Section III			5. Report Date: April 1972
			6.
7. Author(s): W. E. Davis			8. Performing Organization Rept. No.
9. Performing Organization Name and Address: W. E. Davis & Associates, 9726 Sagamore Road, Leawood, Kansas			10. Project/Task/Work Unit No.
			11. Contract/Grant No. 68-02-0100
12. Sponsoring Organization Name and Address: ENVIRONMENTAL PROTECTION AGENCY, Office of Air Programs, Research Triangle Park, North Carolina			13. Type of Report & Period Covered
			14.

15. Supplementary Notes

16. Abstracts

Information is provided regarding the nature, magnitude, and extent of the emissions of copper in the United States for the year 1969. Background information concerning the basic characteristics of the copper industry has been assembled and included. Brief process descriptions are given; they are limited to the areas that are closely related to existing or potential atmospheric losses of the pollutant. The copper emissions and emission factors are based on data obtained from production and reprocessing companies. Additional information was acquired during field trips to inspect the air pollution control equipment and observe processing operations. Emissions to the atmosphere during the year were 13,680 tons. About 64 percent of the emissions resulted from the metallurgical processing of primary copper, and about 20 percent from the production of iron and steel. The combustion of coal was the only other significant emission source.

17. Key Words and Document Analysis. 17a. Descriptors

Air pollution
Copper inorganic compounds
Inventories
Exhaust emissions
Industrial wastes
Metal industry
Iron
Steels
Coal

17b. Identifiers/Open-Ended Terms

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

17c. COSATI Field/Group 13B

18. Availability Statement	19. Security Class (This Report)	21. No. of Pages
Unlimited	UNCLASSIFIED	74
	20. Security Class (This Page) UNCLASSIFIED	22. Price $4.50

APTD - 1129

REPORT

NATIONAL INVENTORY OF SOURCES AND EMISSIONS BARIUM, BORON, COPPER, SELENIUM, AND ZINC

1969

for

ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF AIR PROGRAMS
CONTRACT NO. 68-02-0100

COPPER

SECTION III

by

W. E. Davis

W. E. Davis & Associates
9726 Sagamore Road
Leawood, Kansas

April 1972

GS

14

PREFACE

This report was prepared by W. E. Davis & Associates pursuant to Contract No. 68-02-0100 with the Environmental Protection Agency, Office of Air Programs.

The inventory of atmospheric emissions has been prepared to provide reliable information regarding the nature, magnitude, and extent of the emissions of copper in the United States for the year 1969.

Background information concerning the basic characteristics of the copper industry has been assembled and included. Process descriptions are given, but they are brief, and are limited to the areas that are closely related to existing or potential atmospheric losses of the pollutant.

Due to the limitation of time and funds allotted for the study, the plan was to personally contact all of the primary producers and about twenty percent of the companies in each major emission source group to obtain the required information. It was known that published data concerning emissions of the pollutant were virtually nonexistent, and contacts with industry ascertained that atmospheric emissions were not a matter of record. The copper emissions and emission

factors ~~that are presented~~ are based on the summation of data obtained from production and reprocessing companies. Additional information was acquired during field trips to inspect the air pollution control equipment and observe processing operations.

ACKNOWLEDGEMENTS

This was an industry oriented study and the authors express their appreciation to the many companies and individuals in the copper industry for their contributions.

We wish to express our gratitude for the assistance of the various societies and associations, and to the many branches of the Federal and State Governments.

Our express thanks to Mr. C. V. Spangler, Project Officer, EPA, Office of Air Programs, Research Triangle Park, N. C., for his helpful guidance.

CONTENTS

PREFACE

ACKNOWLEDGEMENTS

SUMMARY 1

Emissions by Source 2
Emissions by Regions 3
Emission Factors 4

MINERAL SOURCES OF COPPER 6

MATERIAL FLOW THROUGH THE ECONOMY. . . 8

Chart 9

USES AND EMISSIONS OF COPPER

Mining and Milling 10
Metallurgical Processing 15
Secondary Copper Production 26
Metal Fabrication 32
End Product Uses of Copper 34
Electrical Equipment 34
Construction 35
Industrial Machinery 37
Transportation 38
Ordnance 41
Miscellaneous 43

OTHER SOURCES OF COPPER EMISSIONS

Coal 50
Oil 54
Iron and Steel 56
Foundries 63
Incineration 64

UPDATING OF EMISSION ESTIMATES 66

TABLES

Table I	Emissions by Source	2
Table II	Emissions by Regions	3
Table III	Emission Factors	5
Table IV	Typical Analysis of Copper Smelter Dusts	23
Table V	Copper Recovered from Scrap Processed in the United States During 1969	27
Table VI	Copper Recovered from Copper-Base Scrap Processed in the United States During 1969	31
Table VII	Average Minor Element Contents of Coals from Various Regions of the United States - ppm	53
Table VIII	Residual Fuel Oil Data	55
Table IX	Spectrographic Analysis of Particulate Discharge from an Open-Hearth Furnace	58
Table X	Typical Emissions from an Electric Arc Furnace	62

FIGURES

Figure I	Material Flow Through the Economy . .	9
Figure II	Typical Copper Smelter Material Balance	24
Figure III	Typical Copper Refinery Material Balance	25

SUMMARY

The flow of copper in the United States has been traced and charted for the year 1969. The consumption was 3,058,000 tons, while primary and secondary production totaled 3,118,000 tons. Imports and exports were 131,000 tons and 200,000 tons, respectively.

Emissions to the atmosphere during the year were 13,680 tons. About 64 percent of the emissions resulted from the metallurgical processing of primary copper, and about 20 percent from the production of iron and steel. The combustion of coal was the only other significant emission source.

Emission estimates for mining, production of primary and secondary copper, and reprocessing operations are based on data obtained by personal contact with processing and reprocessing companies.

TABLE I

EMISSIONS BY SOURCE
1969

Source Category	Source Group	Emissions - Tons	Emissions %
Mining and Milling		190	1.4
Metallurgical Processing		8,700	63.6
Secondary Production		210	1.5
Metal Fabrication		N	
End Product Uses		230	1.7
	Miscellaneous	230	
Other Emission Sources		4,350	31.8
	Coal	1,030	
	Oil	50	
	Iron and Steel	2,760	
	Foundries	50	
	Incineration	460	
TOTAL		13,680	100.0

N - Negligible

TABLE II

EMISSIONS BY REGIONS

	Tons
Region No. 1	8,730
Region No. 2	3,157
Region No. 3	880
Region No. 4	913
TOTAL	13,680

Region No. 1

Arizona
California
Colorado
Idaho
Montana
Nevada
New Mexico
Oregon
Utah
Washington
Wyoming

Region No. 2

Illinois
Indiana
Iowa
Kansas
Michigan
Minnesota
Missouri
Nebraska
North Dakota
Ohio
South Dakota
Wisconsin

Region No. 3

Alabama
Arkansas
Delaware
Florida
Georgia
Kentucky
Louisiana
Maryland
Mississippi
North Carolina
Oklahoma
South Carolina
Tennessee
Texas
Virginia
West Virginia
District of Columbia

Region No. 4

Connecticut
Maine
Massachusetts
New Hampshire
New Jersey
New York
Pennsylvania
Rhode Island
Vermont

EMISSION FACTORS

The emission factors presented herein are the best currently available. They were determined through a combination of methods consisting of: (1) direct observation of emission data and other related plant processing and engineering data; (2) estimates based on information obtained from literature, plant operators, and others knowledgeable in the field; (3) calculations based on experience and personal knowledge of metallurgical processing operations; and, (4) specific analytical results where available.

The basic data used to calculate the emission factors are contained in the files of the Contractor.

TABLE III

EMISSION FACTORS

Mining and Milling	200 lb/1,000 tons of copper mined
Metallurgical Processing	10 lb/ton of copper produced
Secondary Production	300 lb/1,000 tons of copper produced
Metal Fabrication	1 lb/1,000 tons of copper fabricated
Other Emission Sources	
Coal	4 lb/1,000 tons of coal burned
Oil	160 lb/million bbls of oil burned
Blast Furnaces	22 lb/1,000 tons of pig iron produced
Open-Hearth Furnaces	51 lb/1,000 tons of steel produced
Basic Oxygen Furnaces	2 lb/1,000 tons of steel produced
Electric Furnaces	7 lb/1,000 tons of steel produced
Foundries	5 lb/1,000 tons of gray iron produced

NOTE - The emission factors shown above for mining and milling, metallurgical processing, secondary production, and metal fabrication are based on the averages reported by industry. The degree of accuracy is judged to be plus or minus 30 percent.

MINERAL SOURCES OF COPPER

Copper (Cu) is widely distributed in nature and its concentration in the earth's crust averages about 55 ppm. It melts at 1,083 C, its atomic weight is 63.57, and its specific gravity is 8.94.

Copper ore deposits of commercial importance are found throughout the world. The United States is the largest producing country and the other principal producers, named in order of importance, are the U.S.S.R., Zambia, Chile, Canada, the Congo, and Peru.

The minerals of importance as copper ore are azurite, bornite, chalcocite, chalcopyrite, chrysocolla, and malachite. They range in color from yellow, brown, and red to blue, green, gray, and black.

In the United States most of the copper ore is produced in Arizona, Montana, Nevada, New Mexico, Utah, Michigan, and Tennessee. About 98 percent of the domestic production is from ores mined principally for their copper content with the remainder from complex or base metal ores. In addition to the copper that is recovered there are important quantities of arsenic, rhenium, selenium, tellurium,

platinum, silver, gold, and molybdenum that are recovered as by-products.

MATERIAL FLOW THROUGH THE ECONOMY

The domestic copper supply during 1969, of nearly 3.1 million tons, was derived principally from ores and scrap processed in the United States. Only 4 percent was imported in the form of refined copper. Approximately 54 percent was primary copper recovered from foreign and domestic ores, while the other 42 percent was secondary copper reclaimed from old and new scrap. As shown in Figure I, about 85 percent of the primary copper was produced from domestic ores.

The most important use of copper during the year was in electrical equipment and supplies. About 46 percent was used for this purpose, principally in the form of wire and wire products. The second largest quantity, about 15 percent, was required by the construction industry. The demand for copper in the transportation, industrial machinery, and ordnance industries ranked third, fourth, and fifth, respectively.

COPPER

MATERIAL FLOW THROUGH THE ECONOMY - 1969

(Thousand Tons - Cu Content)

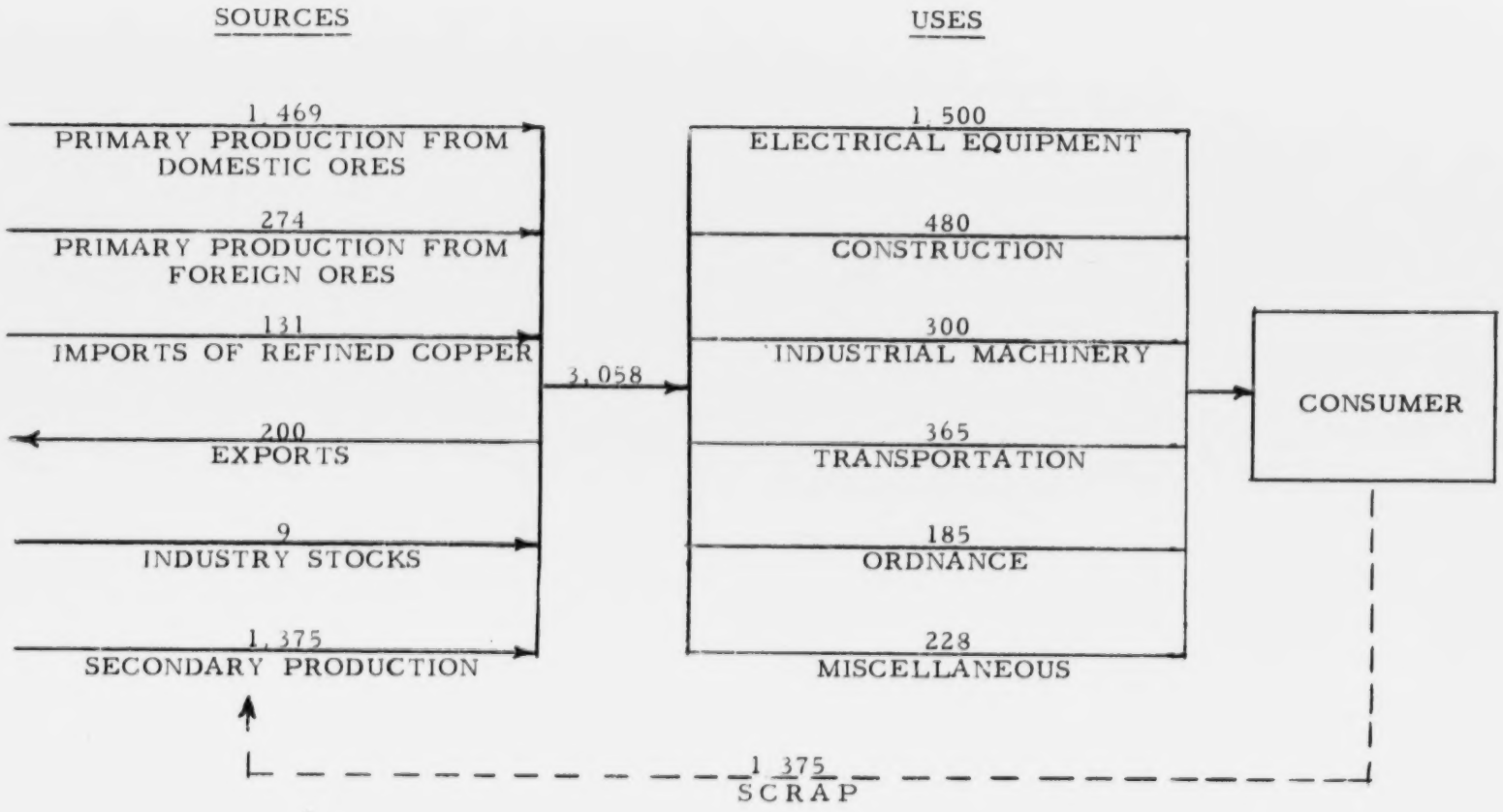

Figure I

USES AND EMISSIONS OF COPPER

MINING AND MILLING

Underground and open-pit copper mining methods are both used in the United States however, the principal method currently employed is open-pit. During 1969 about 88 percent of the ore and 84 percent of the recoverable copper was produced by the open-pit method.

Traditional open-pit operations commence with the stripping of overburden followed by drilling, blasting, and ore handling. The first drilling operation, known as "primary drilling", consists of sinking holes in which to load explosives behind the rock face. Following the blasting, secondary drilling takes place to break boulders that are too large to be handled by loading and hauling equipment. Typically, ore and waste are loaded by large diesel or electric powered shovels and hauling is done by rail for the long haul, or by trucks for a shorter distance. The trend in recent years has been toward usage of larger loading and hauling units. At some locations belt conveyors and skip-ways are used to transport the ore.

Regardless of the type of mine (underground or open-pit),

most of the first steps in processing sulfide and non-sulfide ores are basically the same: drilling, blasting, ore handling, ore removal, hauling, unloading, stockpiling, crushing, and grinding. The ore is dry or perhaps damp when removed from the mine and while crushing, but is wet during the grinding step.

A major development in open pit mining has been the leaching of waste dumps. The overburden, a major part of the waste, is dumped into canyons and gulches to create roadbeds as the mine develops. As these low-grade copper minerals are exposed to slightly acid water, the soluble salts dissolve and are carried to precipitation plants by natural drainage routes. The dissolved copper precipitates on scrap iron, is washed into settling tanks, and is reclaimed as slurry or pulp. This precipitated copper, referred to as "cement copper", usually assays 70 to 90 percent copper and is a suitable smelter feed.

Benefaction of copper ores may be accomplished by flotation or hydrometallurgy. Flotation is the principal method used for concentrating copper sulfide ores, which comprise the bulk of United States copper ore production. Hydrometallurgy is the method employed for non-sulfide ores.

The typical steps for processing sulfide ores are crushing, grinding, classification, flotation, and dewatering. The ore enters the mill by rail car or truck and is discharged over a grizzly into a gyratory crusher. The grizzly, a rather crude sizing device, consists of bars or rails spaced equidistantly over an area: this removes oversize materials. Most of the crushing of the ores is done in 3 steps. The first gyratory crusher reduces the ore to a 6 to 9 inch size. Following screening, the oversized pieces are further crushed in gyratory or cone-type crushers to yield a one to 2 inch product. Water and lime are mixed with the ore and fine grinding is accomplished in rod and/or ball mills. Primary and secondary ball mills are in closed circuit and are equipped with classifiers so that the coarse material circulates for regrinding, while the fine feed material is delivered for flotation.

The finely ground pulp (-200 to -325 mesh) is then conditioned to adjust its alkalinity before feeding to the flotation cells. Air and a small amount of "frother", which might be pine oil or a long chain alcohol, are added in the flotation cells to produce a froth. Small amounts of chemicals referred to as "collectors" are also added, and this causes the copper sulfide

particles to attach themselves to air bubbles and be removed in the froth. The gangue sinks to the cell bottom and is removed as a tailing. Very often 2 or more sets of flotation cells are employed. The bulk of the ore goes through the "rougher" cells and then the concentrate is further upgraded in "cleaner" cells. Following flotation the concentrate is thickened, filtered, and shipped to a smelter. The copper content of the concentrate resulting from these procedures may analyze 15 to 38 percent and the overall copper recovery should average about 83 percent.

Emissions from Mining and Milling - During this study 9 of the 11 major copper mining companies in the United States were contacted concerning the quantity of ore mined, its copper content, and the emissions that occur during mining and milling. Five companies provided some information about 9 mining operations. Although no emission records were available, most of the mine operators agreed there are slight emissions due to handling, crushing, and as a wind loss from tailings.

During 1969 there were 223,752,000 tons of copper ore produced in the United States [1] containing approximately 1.9

---

1. Minerals Yearbook, Bureau of Mines 1969.

million tons of copper. The tailings totaled approximately 218.5 million tons, and the copper content was about 260,000 tons. None of the copper mining companies provided estimates of emissions to the atmosphere; therefore, emissions were estimated by the Contractor at 200 pounds per 1,000 tons of copper mined (Cu content), or 190 tons for the year 1969.

METALLURGICAL PROCESSING

In the United States most of the primary copper is recovered from low-grade sulfide ores using pyrometallurgical procedures. Hydrometallurgy (leaching) can sometimes be used for these ores; however, it is normally employed only for oxide and mixed ores in which oxide minerals predominate. A small quantity of copper is recovered by a by-product during the processing of lead, zinc, and other ores.

There are 4 principal hydrometallurgical methods practiced: (1) in-place leaching; (2) heap leaching; (3) dump leaching; and, (4) vat leaching. In all 4 methods the copper-containing solids are leached with a dilute solution of sulfuric acid. In-place leaching techniques are applicable to shattered, broken, or porous ore bodies. Air and a leach solution are alternately circulated through the fractured rock. The solution drains through tunnels under the ore and is treated to recover the copper.

Heap leaching is generally employed to dissolve copper from an oxide ore. The mined ore is placed in heaps in areas provided with drainage ditches. Leaching and oxidation periods are alternated until the copper can be recovered from the

solution by cementation on iron or by solvent extraction.

Dump leaching is used to recover copper from the low-grade waste material resulting from open-pit copper mining operations. Vat leaching is more suitable for the extraction of copper from crushed and sized oxide or mixed oxide-sulfide ores that contain more than 0.5 percent acid-soluble copper.

From the standpoint of air pollution, the emissions from pyrometallurgical extraction processes are a far greater problem than those from leaching. The major steps are roasting, reverberatory smelting, and converting. The object of roasting copper sulfide ores and concentrates is to regulate the amount of sulfur so that the material can be efficiently melted and to remove certain volatile impurities such as antimony, arsenic, and bismuth. However, in current practice the concentrate produced from some sulfide ores is sufficiently controlled at the concentrator to eliminate roasting prior to reverberatory smelting.

Various types of feed materials may be delivered to a smelter. The largest portion consists of copper and iron sulfide concentrates usually containing 15 to 32 percent copper. Much smaller quantities of sulfide and oxide ores containing 4 to 6 percent

copper also may be a part of the smelter feed, as well as precipitates containing 70 to 85 percent copper.

Since concentrates and precipitates arrive at the smelter containing some free moisture, predrying may be required. Rotary or multiple-hearth dryers are used to drive off about half of the moisture.

Roasting is deemed necessary when the feed material is low in copper and high in iron and sulfur. The roaster removes a part of the sulfur by converting it to sulfur dioxide, while an equivalent portion of the iron is oxidized. Multiple-hearth roasters are in general use although some plants have the more modern fluid bed roaster facilities. The calcine from the roaster is charged to the reverberatory furnace where iron oxide combines with silica to make a slag while the copper, iron, and the remaining sulfur are left in the product material, known as matte. The molten matte is removed from any of several holes and conveyed to the converter aisle. The immediate matte tapping area is enclosed and fumes are exhausted to the atmosphere. The slag is removed through slag skimming holes, transported either molten or granulated in water, and dumped outside the smelter building. Collection and recovery of furnace gases is a

major problem. A main dust collector, usually an electrostatic precipitator, is used and may have an efficiency of 95 to 99 percent.

Next, it is the function of the converters to oxidize and separate the iron and sulfur from the matte. This is accomplished by blowing air into the liquid matte through openings in the converter called "tuyeres". A silica flux is added to combine with the iron oxide and form a slag to be skimmed off and returned to the reverberatory furnace. As more matte is added to the converter, the process is repeated until a suitable charge of copper sulfide is accumulated. Then continued blowing eliminates the remaining sulfur resulting in a blister copper more than 99 percent pure, which can then be removed to holding furnaces for casting or further refinement. The gases coming from a copper converter are heavily laden with dusts containing a large quantity of copper. The blister copper produced from the converter is the principal product of a primary copper smelter.

The amount of dust in a smelter will depend on variables such as the fineness of the charge, the amount of agitation in charging and working, the amount of volatile metals in the ore and the temperatures used. The value of dust recovery

is considerable since the copper content of dusts from the roaster may be 10 percent, from the reverberatory about 25 percent, and from the converter as much as 45 percent. The lead content also is usually high. After the gases, fume, and dusts leave the furnaces and enter the flues they are cooled and lose velocity. The coarser dust and some fume settles to the bottom to wait for removal. Fine dust and fume is collected by electrostatic precipitators and recycled for direct resmelting in the reverberatory furnace.

Fire refining and anode casting operations may be included at copper smelters. Copper from the converter is either partially fire-refined and cast into anodes for electrolytic purification, or fire-refined to a practical limit to achieve a commercially salable product; the latter is done when the silver and gold contents are very low.

The fire refining is commonly done in either a small reverberatory furnace or one of the tilting cylindrical type. A charge of blister copper is oxidized by blowing air through iron pipes into the charge. The slag is skimmed several times and returned to the converter. After the oxidation procedure, the bath is covered with coke and logs are forced into the metal. As the destructive distillation of the wood occurs,

hydrogen, hydrocarbons, carbon monoxide, and water vapor evolve. When the desired stage called "tough pitch" is reached, charcoal is spread on top to maintain the desired composition until the metal is cast.

Copper which is to be further purified is cast into anodes and sent to an electrolytic refinery. The impure copper anodes are dissolved electrolytically in an electrolyte solution of copper sulfate and sulfuric acid. The copper alone migrates to and is deposited at the cathode. The impurities in the anode either dissolve in the electrolyte or fall to the bottom as slime. The purified copper is then melted and cast into bars for shipment, and the slimes are treated further for recovery of precious and rare metals.

Overall recovery of copper averages about 97 percent at copper smelting and refining facilities, but at plants producing primary lead and zinc the recovery of copper from such ores and concentrates averages 85 percent.

Throughout processing from the ore to the final product there are fumes, dusts, slags, and residues containing copper that are discharged from dryers, roasters, furnaces, converters, and other equipment. In most cases these

materials are collected, retreated, and recycled. At one smelting and refining complex where copper, lead, and zinc ores are processed there are several locations where fume is recycled. For example, fume from the copper roaster enters an electrostatic precipitator and the dust collected is returned to the roaster. The recycling is continuous, except periodically the dust may be directed elsewhere for recovery of certain materials that build up in the system. Fume from the reverberatory furnace and converter also enters an electrostatic precipitator. dust collected is forwarded to a dust roaster and on to the lead processing circuit. Fume from the lead blast furnace is directed to another electrostatic precipitator and the resulting dust is returned to the lead circuit. Speiss from the lead blast furnace is directed to the copper roaster.

These are only a few of the numerous recycles and interchanges between the copper, lead, and zinc circuits.

Emissions from Metallurgical Processing - During this study 9 copper smelting and refining companies were requested to provide data concerning the atmospheric emissions at 16 smelters and 11 refineries. Six companies responded with some information about 10 smelters and 7

refineries, while 3 companies either refused to cooperate or ignored the request for information.

Table IV shows the analyses of particulate matter discharged from the stack of a copper smelter, while Figures II and III give the material balance for a typical copper smelter and a typical copper refinery.

The data obtained from 6 industrial sources regarding metallurgical processing of copper-bearing ores and the production of copper show that emissions to the atmosphere during processing range upward to more than 40 pounds of copper per ton of primary copper produced, averaging about 10 pounds per ton.

During 1969 copper emissions to the atmosphere in the United States due to metallurgical processing totaled 8,700 tons.

TABLE IV

TYPICAL ANALYSIS OF COPPER SMELTER DUSTS

Element		From Roasters	From Reverberatory Furnaces	From Converters	From Stack
Copper	%	5.2	2.9	1.12	1.03
Iron	%	6.6	1.6	1.2	2.4
Lead	%	7.6	30.5	47.1	23.4
Sulfur (as SO_2)	%	5.8	2.1	8.2	7.8
Zinc	%	1.7	8.3	3.2	6.3
Arsenic	%	43.0	25.7	9.6	21.8
Antimony	%	5.3	3.0	1.6	4.6
Bismuth	%	0.4	1.11	1.64	1.0
Cadmium	%		0.71	1.15	0.8
Silver	oz/ton	7.6	18.6	10.9	10.1
Gold	oz/ton	0.02	0.04	0.02	0.02

Source - Private communication.

TYPICAL COPPER SMELTER MATERIAL BALANCE

(100 Tons - Cu Content)

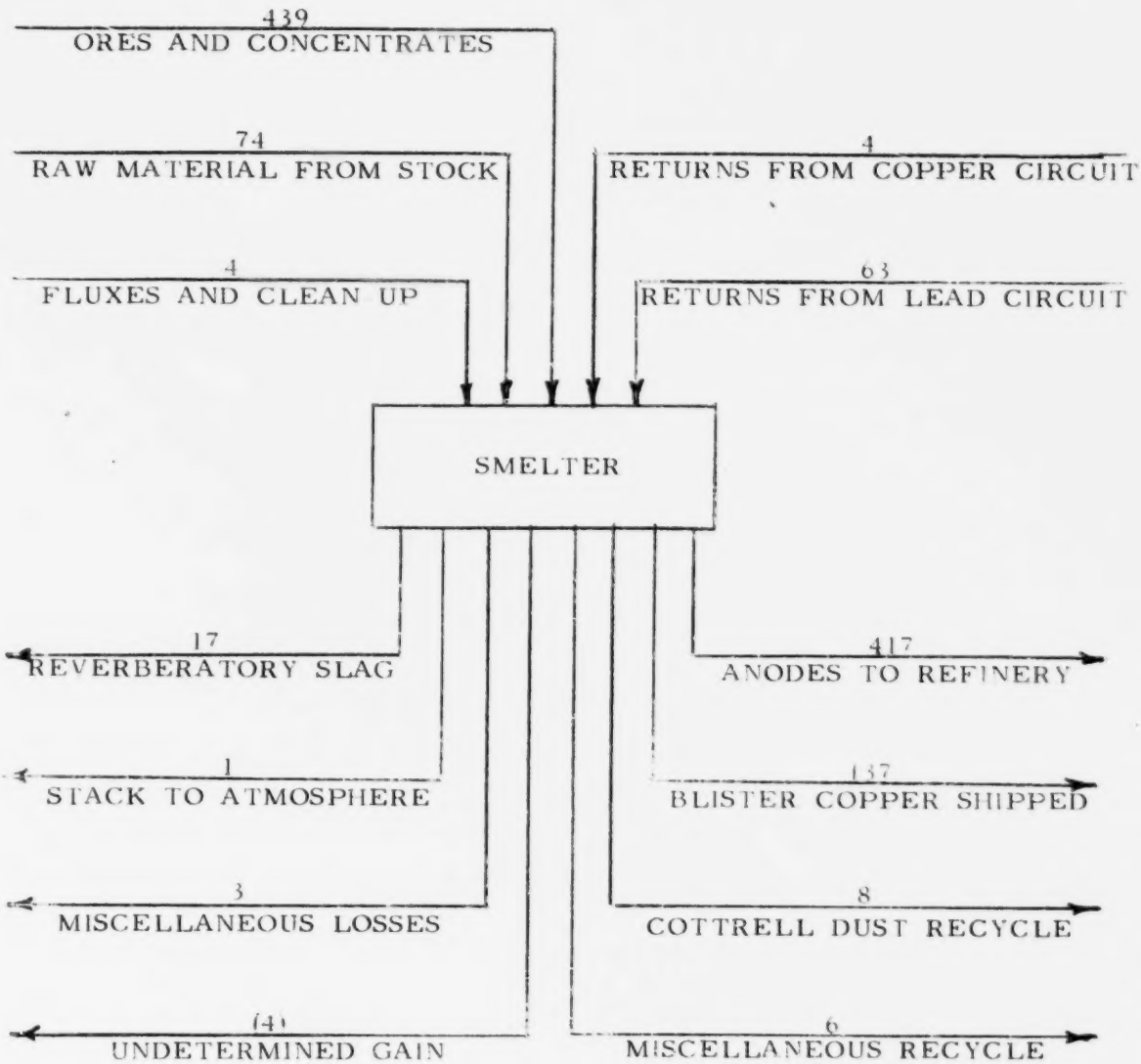

Figure II

TYPICAL COPPER REFINERY MATERIAL BALANCE

(100 Tons - Cu Content)

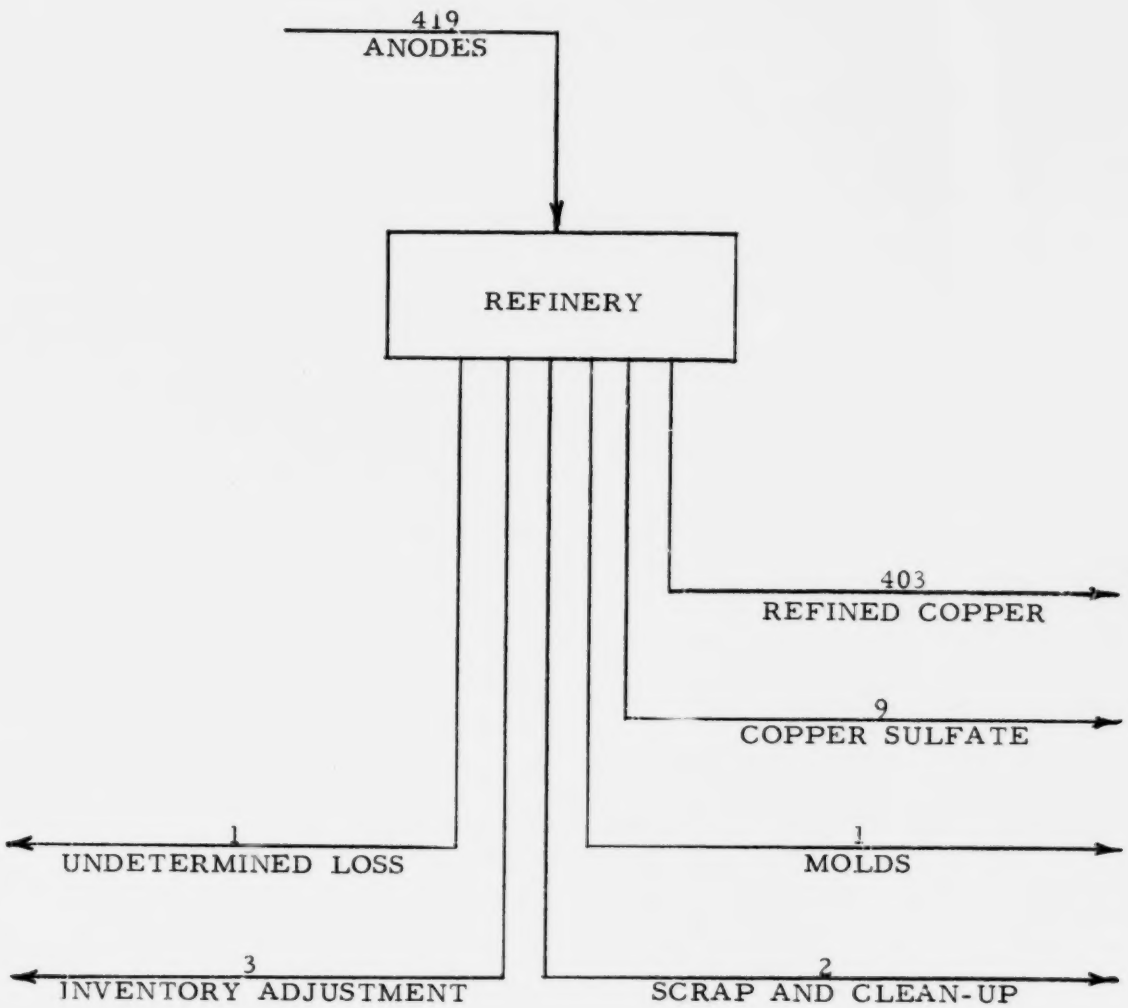

Figure III

SECONDARY COPPER PRODUCTION

In the United States the secondary copper industry is very important. It accounts for a significant part of the total copper supply and it is the largest of the nonferrous secondary metal industries. The production of secondary copper during 1969 was 1,375,493 tons while primary production was 1,742,815 tons.

The industry includes several thousand scrap dealers, several hundred foundries, the brass mills, the secondary smelters, and the primary smelters. It employs many processes unique to the industry as well as many currently used by the producers of primary copper.

Secondary copper is produced in both alloyed and unalloyed forms from new and old scrap, as shown in Table V. The new scrap is that resulting from fabrication and manufacturing operations while old scrap is defined as items discarded after serving a useful purpose.

When dealing with scrap metal various problems are involved that are different than those encountered when dealing with ores and concentrates. There are many types of scrap. Some are relatively pure and others are alloys containing various

TABLE V

COPPER RECOVERED FROM SCRAP PROCESSED IN THE UNITED STATES DURING 1969 1/

(Short Tons)

Kind of Scrap	
New Scrap:	
Copper-base	787,727
Aluminum-base	12,595
Other	281
TOTAL	800,603
Old Scrap:	
Copper-base	568,769
Aluminum-base	4,973
Other	1,148
TOTAL	574,890

Form of Recovery	
As Unalloyed Copper:	
At Primary Plants	412,843
At Other Plants	101,750
TOTAL	514,593
In Brass and Bronze	820,945
In Alloy Iron and Steel	2,570
In Aluminum Alloys	32,826
In Other Alloys	735
In Chemical Compounds	3,824
TOTAL	860,900

1. Minerals Yearbook Bureau of Mines 1969.

amounts of copper. Even though scrap metal may be pure copper, it is often intimately associated with non-metallic materials such as chemicals, dirt, grease, insulation, moisture, oil, paint, plastics, rubber, and many others.

Raw material preparation is an important operation in the secondary copper industry. The dealer must first identify and sort the scrap. Small dealers may rely principally on visual inspection and experience. Larger dealers can justify the use of more precise methods such as examination of metal color and structure, filing and drilling, chemical spot testing, and rapid chemical analysis. When the scrap is received at smelters, brass mills, and other processing facilities, it must be inspected further and materials sorted to assure proper product quality control. These additional tests may include sampling and melting for spectrographic analysis.

After sorting, some scrap material is pre-treated mechnically and some requires a preliminary furnace treatment. Insulation and lead sheathing are removed from wire and cable by hand or by machine stripping. Drillings, clippings, and turnings are usually passed over a magnetic separator to remove tramp iron. Bulky and sponge like materials are often

crushed and compacted for easier handling, while large solid items are cut or broken to reduce the size.

The preliminary furnace treatment prior to smelting is usually at a rather low temperature and various types of furnaces are employed. A muffle furnace or kiln may be used to drive off moisture, oil, and other organic impurities. For the removal of solder, babbitt, and lead from radiators, bearings, and similar articles, a sweating operation is required. The simplest sweating furnace is the sloping-hearth type; however, many others are used for this purpose, including rotary kilns, reverberatories, pots, and tunnel furnaces.

After the raw material has been prepared the remaining procedures for melting and refining are principally material handling and pyrometallurgical operations utilizing blast furnaces, reverberatories, rotary furnaces, converters, cupolas, and crucible furnaces. There is no basic difference in the melting and refining actions in these furnaces, but there are differences in the types of alloys handled, the furnace capacities, the condition of charge materials, and the methods for heating.

During 1969 the brass mills were the largest users of scrap

materials (see Table VI). Principally they used new materials while the primary producers consumed about an equal amount of old and new. The secondary smelters ranked third in consumption of raw material using mostly old scrap. The primary smelters produced about 80 percent of the refined copper while brass and bronze ingots were the principal products of the secondary smelters.

Emissions from Secondary Copper Production - Data obtained from industry during this study shows that copper emissions to the atmosphere in 1969 averaged 300 pounds per 1,000 tons of secondary copper produced. Published information agrees with the above data. Particulate emissions from refining furnaces in the brass and bronze ingot industry average 60 to 80 pounds per ton of ingots produced and the range of copper content is from 0.05 to 1.0 percent [1].

During 1969 copper emissions to the atmosphere due to the production of secondary copper totaled 210 tons.

---

1. "Air Pollution Aspects of Brass and Bronze Smelting and Refining Industry." National Air Pollution Control Administration Publication No. AP 58 Nov., 1969.

TABLE VI

COPPER RECOVERED FROM COPPER-BASE SCRAP PROCESSED IN THE UNITED STATES DURING 1969 [1]/

(Short Tons)

Recovery Plant	From New Scrap	From Old Scrap	Total
Brass Mills	480,093	38,541	518,634
Primary Producers	215,561	197,282	412,843
Secondary Smelters	72,515	277,240	349,755
Foundries and Manufacturers	18,687	52,856	71,543
Chemical Plants	871	2,850	3,721
TOTAL	787,727	568,769	1,356,496

1 Minerals Yearbook Bureau of Mines 1969.

METAL FABRICATION

In the metals industry the term fabrication usually refers to the shaping and finishing of metals and metal alloys into the standard sizes, finishes, and shapes that are needed by the construction industries and the manufacturers of finished products. In the copper and copper alloy field, fabricators are concerned with producing tubes, rods, sheet, and wire, all in varying sizes.

The metals are generally received as cathodes, ingots, slabs, cakes, or bars in large quantity shipments from the refineries. The fabrication phase begins with heating and melting, and the melting furnaces generally used by fabricators in the copper industry are electric induction furnaces. These furnaces are charged with a layer of scrap and then the high melting constituents. When the charge is melted, the furnace is skimmed of impurities and dross through a door and the surface of the metal is covered with charcoal to prevent further oxidation. About 60 percent of this molten metal is then poured from the furnace into casting molds and recharging continues.

Following the casting of the metal into appropriate shapes,

the metal may be heated for hot working, for reworking, for stress relief, or to obtain final temper. The heating preparatory to hot working usually requires a higher temperature than the annealing for cold working. Materials for hot working may be rolled, conveyed, or pushed through a furnace and then sent to the rolling mill. Materials for annealing are placed in batch or continuous type furnaces and then enter a separate cooling chamber before exposure to the air.

Emissions from Metal Fabrication - Information obtained during this study regarding rolling, extrusion, cold drawing, pointing, pickling, and annealing operations has been used to estimate copper emissions due to metal fabrication. The range of atmospheric emissions reported varied from less than 0.5 to as much as 20 pounds per thousand tons of copper processed. The average was one pound per thousand tons.

During 1969 the copper emissions to the atmosphere due to metal fabrication totaled 2 tons.

END PRODUCT USES OF COPPER

In the United States about 40 percent of the primary and secondary copper is used in the commercially pure form, principally because of its excellent properties as a conductor of electricity. Approximately 50 percent is consumed as an alloying element in the production of brass, bronze, nickel-silver, cupronickel, and numerous special alloys.

The largest application of copper during 1969 was in the electrical industry. Nearly 50 percent was consumed in the manufacture of electrical equipment and supplies while the construction, transportation, industrial machinery, and ordnance industries used 5 to 15 percent each.

Manufacturers in all industries were contacted during this study concerning materials handling, manufacturing operations, pollution control equipment, and atmospheric emissions as related to their use of copper. Information from them indicates that copper emissions to the atmosphere are negligible except for certain miscellaneous uses described herein.

Electrical Equipment - Tough-pitch copper is the predominant type used by the electrical industry. It has good mechanical properties and high electrical conductivity at minimum

cost. Although used principally in the form of wire and cable, there are many brass and bronze products, including castings, that enter into the manufacture of electric motors, power generators, motor-generator sets, dynamotors, fans, blowers, controls, switchgear, transformers, and related apparatus. In the home the use of copper is equally important. It is found in household refrigerators, freezers, laundry equipment, dishwashers, disposals, vacuum cleaners, air conditioners, television sets, radios, telephones, toys, record players, tape recorders, lighting fixtures, and power tools.

Copper in electrical equipment manufacturing is used principally in a series of mechanical operations. Wire received from metal fabricators may be insulated and wound into coils for generators, motors, transformers, and solenoids. Bars, sheet, and strip may be sawed, stamped, sheared, drilled, formed, and machined in various ways as required for equipment components.

Construction - Copper, due to its high resistance to corrosion, has found extensive and varied uses in the construction of buildings. The roof is one of the most important components of a structure and when properly erected, copper roofs resist indefinitely the penetration of rain, snow, and sleet.

There are 3 types of roofs: batten seam, standing seam, and flat seam. All are normally constructed of cold-rolled sheet copper; however, corrugated copper sheets may be used.

Because its ductility assures easy fabrication, copper is ideally suited as a flashing material to insure against leaks at surface intersections whether vertical, horizontal, curved, or sloped. Flashings may be found on roofs, doors, windows, skylights, ventilators, and expansion joints.

Copper's resistance to corrosion has long made it a sought after material for tubing to carry water. The development of the copper water tube with soldered fittings has made this material available to the small home owner for plumbing, heating, air conditioning, and sprinkler systems. Radiant heating systems use large quantities of copper tubing hidden in floors, walls, and ceilings. Radiant heating can also be used for snow removal by embedding tubing in concrete walks and driveways.

Copper has many other uses in construction. Gutters and leaders to convey rain water away to designated areas are best constructed with cold rolled copper. A 16 ounce sheet

of copper may be placed over the top of a masonry foundation to form a termite barrier. Sheet copper and copper rod are employed in the construction of louvers, ventilators, lightening rods, and fasteners. Domestic furnaces, kitchen stoves, and hot water heaters are often supplied with oil or gas through copper tubes because of its stability and ease of installation.

Brass and bronze are popular hardware materials used in locks, doorknobs, handles, letter slots, mail boxes, house numbers, door knockers, hinges, door holders, door closers, push and kick plates, window latches, railings, curtain rods, name plates, elevator doors, window frames, fireplace hoods, light fixtures, andirons, and many other household decorative items.

From the standpoint of copper emissions to the atmosphere, the manufacturing and installation operations used in connection with copper construction materials are similar in many respects to those used in the manufacture of electrical equipment.

Industrial Machinery Large quantities of bronze castings are employed in the machine tool industry as gears, bearings, and special purpose parts such as shifter forks and

feed nuts. In all machinery parts the copper alloys are used to prevent seizure or scuffing with the mating steel part.

In mechanical power transmission and linkage systems, the use of copper alloy parts is common where scuffing and galling are to be avoided. For instance, a bronze bearing is used in earthmoving equipment in the hitch between the power unit and the conveyor truck. In high pressure hydraulic systems, bronze parts are often employed to prevent seizing.

The textile industry finds many uses for bronze in intricate machinery parts. Bronze is used because of its corrosion resistance, high strength, and castability.

Numerous miscellaneous applications involving slides and clutches indicate the usefulness of the copper-base alloys for combinations of castability, strength, wear, corrosion resistance, and machinability.

Transportation - Copper and its alloys possess combinations of properties which make them useful for a variety of functions in the transportation industry. High thermal and electrical conductivity, good corrosion resistance, good bearing properties, softness, and ease of fabrication are some of the most important properties. High heat conductivity is

needed in radiators, heater cores, and oil coolers. The starting, lighting, and ignition circuits require high electrical conductivity. Copper's corrosion resistance makes copper and its alloys useful in fabricating radiators exposed to air, lubricants, and coolants. By utilizing copper these parts can be made without protective films. Where an airtight seal is required, gaskets and washers are often fabricated of copper because of its softness. The ductility of copper is valuable in the manufacturing of parts where deep drawing and forming operations are involved. Copper can also be easily soldered and brazed for various assemblies.

Many automotive parts are prepared from copper sheet, strip, and plate. The parts are generally formed by some combination of drawing, stamping, riveting, soldering, and brazing. A partial list of these parts includes gaskets, washers, spacers, thrust bearings, retainers, gears, springs, housings, thermostats, carburetor floats, fuel and oil gages, oil coolers, dials, and electrical contacts. The largest single use of copper and copper-base alloys is in radiators and heaters. The radiator contains top and bottom tanks, filler neck, overflow tube, drain cock, core, and mounting shell. All these parts are fabricated from copper or copper-base alloys.

Bars and rods of copper, brass, and bronze may be machined and cold formed to produce parts. These may include nuts, screws, bolts, elbows, tees, connectors, adapters, studs, rivets, buttons, knobs, gears, dowels, valve guides, spacers, jets, and needles.

Copper tubing is used in oil, fuel, brake, and coolant lines because it resists corrosion. This same property is important for tubing in instrument assemblies, oil coolers, and heaters.

Copper wire is required for many parts including generators, starter motors, windshield wiper motors, coils, relays, switches, instrument wiring, lighting, and ignition systems.

Metal powders also find some use in vehicles for self-lubricated bearings where the sintered parts are impregnated with liquid or solid lubricants. These bearings are used in transmissions, water pumps, distributors, starter motors, generators, windshield wipers, and heater fans.

In the area of transportation the railroad, marine, and aircraft industries should have special mention. In general, the excellent resistance of copper base alloys to salt water pitting, cavitation, and corrosion along with their other

processing characteristics leads to widespread use in marine applications. Copper and copper alloys are useful both structurally and in electrical applications. Structurally, copper may be in the hull, deck, funnel, superstructure, and rudder. It may be a part of the distillation plant, boiler, turbines, propeller shaft and bearings, propeller, speed reducer, and bull gear. Also copper, brass, and bronze are utilized extensively for hardware and decoration.

In the aircraft industry most of the copper is found in the wiring and electrical components. Some large planes use as much as 3,000 pounds in the electrical systems.

Ordnance - Malleability and work hardenability are the two outstanding characteristics which permit the development of the various properties required in ordnance items such as rotating bands, bullet jackets, bearings, springs, detonators, fuse parts, primer cups, and cartridge cases.

The largest consumption in ordnance has been in cartridge brass for ammunition. This brass alloy of 70 percent copper and 30 percent zinc is well suited for cartridge cases, which are made normally by a cup and draw process using strip brass. The blanking and cupping operations are

frequently combined through the use of a double-acting press. Annealing operations are used to condition the metal for subsequent deep-drawing operations in which the sinking and ironing result in as much as a 60 percent reduction in the side-wall volume. Other steps include bumping and head-turning. A final trim to control the overall length of the case is followed by a venting operation and a mouth anneal, which softens the neck of the case so it will function satisfactorily when a bullet is assembled in it.

The second largest use of copper in ordnance has been the projectile rotating bands, which are usually made of pure copper. The properties required in a rotating band are good bearing, engraving, and shear properties, along with low resilience, since the band must engrave readily, spin the projectile, and not wear the barrel of the rifle when the projectile is fired.

The uses of copper-base metals in mobile mounts, jeeps, trucks, and tanks are similar to those discussed in the transportation applications; usage in field telephones, walkie-talkies, power generators, distribution systems, radios, and radar is like that in electrical applications.

Miscellaneous - Although most of the copper is used in alloys or as commercially pure metal, there is about one percent in the various compounds used in pharmaceuticals, pyrotechnics, pigments, paints, wood preservatives, fuel additives, glass, catalysts, ceramics, textiles, dyes, rubber, plastics, photography, electroplating, and products for various agricultural applications.

Copper sulfate is the most common compound of copper and is often used for producing other compounds. It is usually prepared by the action of hot sulfuric acid and air on copper shot. This produces a copper sulfate solution. Copper carbonate can be precipitated chemically as a green powder by adding a copper sulfate mixture to a solution of soda ash. Bordeaux Mixture for agricultural use is a solution of copper sulfate added to a lime suspension. Cuprous cyanide is prepared by adding potassium cyanide to a copper sulfate solution. This produces a precipitate of cupric cyanide, which decomposes during boiling or drying to yield cuprous cyanide.

Other important copper compounds are made in a variety of ways. Cuprous oxide is prepared in a commercially pure form by furnace reductions of mixtures of copper oxides with copper brought to a high temperature (above 1,900 F)

and quickly cooled. Cupric oxide occurs when copper is oxidized at a temperature above 550 F. It can be manufactured by furnace oxidation or by indirect oxidation of copper in the ammonia leaching process for the recovery of copper from ores. Chlorine is passed into molten cuprous chloride containing excess copper metal to produce the solid salt of cuprous chloride. The molten mixture is cast, cooled, and sometimes ground to a powder. A cupric chloride crystal can be made by reacting chlorine with copper in a cupric chloride bath. The cupric chloride solution occurs after chlorine is passed up a tower packed with scrap or shot copper. A solution of copper nitrate is prepared by dissolving cupric oxide, hydroxide, or carbonate, or copper metal, in nitric acid. Basic cupric acetate is obtained by the action of acetic acid and air on copper scrap.

Agricultural - A wide variety of copper compounds and mixtures are valuable as fungicides. Copper sulfate was used extensively in the past, but now other compounds have become the principal means of protecting plants from disease. Bordeaux Mixture is a common fungicide that is low in cost. Burgundy Mixture is similar to Bordeaux, although a little more expensive. Copper acetate, copper oxychloride, and

copper-ammonium compounds all serve as fungicides for various plants.

Some copper compounds are utilized as insecticides. Paris Green, a mixture of white arsenic, basic copper carbonate, and acetic acid, is one of the most well known. It can be used as a spray or mixed with flour and lime for dusting. The copper salts may be given directly to sheep to control worms. Microscopic organisms in water can be eliminated by using copper sulfate powder for dusting the surface. Copper oxide has been used for seed treatment for many years and has yielded excellent results. Even though copper compounds and mixtures are used in agriculture, there is no reliable information regarding the quantity actually consumed for that purpose during 1969.

Electroplating Copper is employed extensively in the electroplating industry, sometimes as a final finish, but more often as a coating on steel before other deposits are made. It is also universally used for plating on zinc base die castings.

Many types of copper plating baths are available because of the wide variety of uses of copper in industry. The cyanide bath is generally for "copper striking" steel and for the

initial plate on zinc-base die castings. Rochelle baths are similar to cyanide baths except the Rochelle salt addition permits higher operating current densities. Copper sulfate baths are inexpensive, fast, and easily controlled. They are very popular but cannot be used directly on steel.

Paints and Pigments - Inorganic compounds of copper have been used in paint pigments, but the current use in paints is usually because of some desirable property other than color. They are used in marine anti-fouling paints and in poisonous paints to protect timber from certain insects and fungi.

Verte antique or copper green is a fine pigment for imitating a copper finish. It gives a corroded copper effect that is superior to other pigments. Copper compounds may also be used in preparing azo dyes, in dyeing polyacrylic fibers, and in treating textiles to improve lightfastness.

Glass - In the glass industry copper is most often used in the form of copper oxide as an additive to impart flex and abrasion resistance to glass fibers and as a polishing agent for optical glasses. It may also be added to the glass batch as a pigment.

Even though glass mixing procedures vary from small manual

operations to full automation, the mixing and charging are done with the materials dry or nearly dry, and there is a loss due to dusting. The furnace itself may be a small covered or uncovered clay pot or a large "continuous tank" furnace. Following the melting, the glass may be formed by blowing, pressing, casting, rolling, or drawing. Final operations include finishing and secondary forming.

Fuel Additives - Numerous compounds that contain heavy metals are marketed as additives for fuel oil. Some are used to modify the physical characteristics of the fuel, while others are intended to improve combustion. These additives, when used as recommended by the manufacturers, increase the copper content of the fuel an average of about 2 ppm. During this study more than 200 additives were examined and 16 were found that contained copper [1]. However, reliable information was not available concerning the actual amount of copper used in additives.

Catalysts - The copper chromium oxide catalyst is useful

---

1 "Effects of Fuel Additives on Air Pollutant Emissions from Distillate Oil Fired Furnaces" Environmental Protection Agency Office of Air Programs Publication No. AP-87 June, 1971.

for the hydrogenation of aldehydes and ketones to alcohols, of esters to alcohols, and of amides to amines. It is prepared by the thermal decomposition of copper ammonium chromate formed by the reaction of copper nitrate with ammonium dichromate in an ammonium hydroxide, ammonium carbonate solution.

Cupric sulfate may be used for some catalytic oxidation procedures, and cupric oxide has been an intermediate reactant in converting barium compounds.

Pharmaceuticals - Copper is an essential element in both plant and animal metabolism, and trace amounts of copper compounds must be available for proper functioning of living organisms [1]. However, copper in excess of requirements is toxic to both plants and animals.

Copper compounds may be found in intestinal antiseptics, vitamin preparations, astringents, bactericides, and emetics for certain poisons.

---

[1] Nikitin, A. A. "Production and Use of Trace Salts in Fertilizers" in Chemistry and Technology of Fertilizers Reinhold Publishing Corp., New York, N. Y. 1960.

Emissions Due to Miscellaneous Uses of Copper - Although more than 100 industrial companies were contacted during this study concerning processing of copper and copper compounds, there was only a relatively small amount of information available regarding emissions and the quantity of copper consumed.

The Contractor's estimate for copper emissions to the atmosphere resulting from the miscellaneous uses of copper compounds and mixtures totaled 230 tons for the year 1969. Information obtained from 10 companies was used as a basis for the estimate. Even though they did not report emissions, the information furnished about operating procedures and methods of handling copper-bearing materials was some help. In most instances the emissions were judged to be due principally to mechanical operations, including unloading and handling.

OTHER SOURCES OF COPPER EMISSIONS

COAL

A search has been conducted and information has been obtained regarding the copper content of coal, ash of coal, and fly ash emissions.

With respect to fly ash, there is a study of emissions from coal fired power plants which shows the analysis of several fly ash samples. Six power boilers were tested, each a different type, and each value reported was the average of at least 2 tests. Two of the boilers were fired with Illinois coal; 2 burned Pennsylvania coal, one used some coal from Ohio and some from West Virginia; one burned part Kentucky and part West Virginia coal. The coal burned during the tests represented only a small portion of the coal mined in the various regions of the United States.

Copper concentrations in the fly ash samples taken before fly ash collection ranged from 1.9 to 25.0 x 10^{-4} grains per scf [1]. The average was 10.5 x 10^{-4} grains per scf.

---

1. Cuffe, Stanley T. and Gerstle, Richard W. "Emissions from Coal Fired Power Plants" Public Health Service Publication No. 999-AP-35 1967

Calculations have been made based on:

(a) 516,084,000 tons of bituminous and anthracite coal consumed in the United States during 1969 [1];

(b) 160 scf of flue gas per pound of coal;

(c) 10.5×10^{-4} grains per scf copper concentration;

(d) 85 percent efficiency of control and

(e) 90 percent application of control.

The copper emissions calculated in this manner totaled 2,910 tons.

$$\frac{516,084,000 \times 160 \times 10.5 \times 10^{-4} \times 2,000}{7,000 \times 2,000} \left[1 - (0.85 \times 0.90)\right] = 2,910$$

During the combustion of coal, copper is discharged with the ash, part with the bottom ash and part with the fly ash. The fly ash averages about 65 percent of the total ash.

Many samples of coal have been analyzed and the copper content reported as shown in Table VII. Calculations have been made based on:

(a) 516,084,000 tons of bituminous and anthracite coal consumed in the United States during 1969 [1];

---

1 Minerals Yearbook, Bureau of Mines, 1969.

(b) 13 ppm average copper concentration in coal;

(c) fly ash 65 percent of total ash

(d) 85 percent efficiency of control; and

(e) 90 percent application of control.

The copper emissions calculated in this manner totaled 1,030 tons.

$$516,084,000 \times 13 \times 10^{-6} \times 0.65 \left[1 - (0.85 \times 0.90)\right] = 1,030$$

In this report, the figure of 1,030 tons is used as the copper emissions to the atmosphere during 1969 due to the combustion of coal.

TABLE VII

AVERAGE MINOR ELEMENT CONTENTS OF COALS FROM VARIOUS REGIONS OF THE UNITED STATES - PPM

Region	Ash Content of Coal - %	Cu Content of Coal - ppm
Northern Great Plains	13.42	15
Eastern Interior	6.16	11
Appalachian	6.11	15
Western and Southwestern	NR*	11
. Average Copper Content in Coal		13

*Not reported.

NOTE - The abo e table based on Geological Sur ey Bulletins 1117 C and 1117-D 1966 and 1967.

OIL

In order to estimate the copper emissions to the atmosphere due to the combustion of fuel oil, it was necessary to determine the copper content and the quantity of oil received from numerous foreign and domestic sources. Some data were obtained from publications and some from major oil companies.

The copper content in crude was shown in more than 100 samples of foreign and domestic oils; however, the situation was somewhat different with respect to the metal content of residual oils. The only reliable information available seemed to be that regarding nickel and vanadium. Analyses showing the copper content were virtually nonexistent, except for 6 samples of imported oil analyzed for the Environmental Protection Agency, Office of Air Programs, during 1971. The average copper content of the 6 samples was 0.47 ppm.

The residual oil used in the United States during 1969, exclusive of use in vessels, was 639 million barrels [1]. This

---

1. "Sales of Fuel Oil and Kerosine in 1970", Mineral Industry Surveys: U. S. Department of the Interior, Bureau of Mines: Oct. 1, 1971.

oil containing copper at 0.47 ppm (average) was used by industrials, electric utility companies, railroads, oil companies, and the military, as well as for heating (Table VIII).

TABLE VIII

RESIDUAL FUEL OIL DATA

Residual Fuel Oil Burned - 1969 (bbls)	639,048,000
Pounds per Barrel	340
Copper Content of Oil (ppm)	0.47

Based on the data in Table VIII, the copper emissions to the atmosphere due to the combustion of residual oil totaled 50 tons during 1969.

IRON AND STEEL

Steel mills are important sources of copper emissions to the atmosphere. Even though very little copper is used in the production of steel, trace quantities enter the process in the raw materials. In the blast furnace, where iron ore is reduced to pig iron, there is a partial removal of impurities. In the open-hearth, basic oxygen, and electric furnaces, further purification takes place as pig iron and scrap are converted to steel.

Blast Furnace - As the gas leaves the blast furnace, it contains large quantities of particulates averaging about 150 pounds per ton of pig iron [1]. However, it is subsequently cleaned and used as fuel. The gas cleaning is accomplished in 2 or 3 stages and the annual overall efficiency is estimated by the Contractor at 97 percent.

During 1969, the pig iron produced in the United States totaled 95,472,000 tons [2]. The copper content of the particulate

---

1. "Air Pollutant Emission Factors" Environmental Protection Agency Preliminary Document Apr., 1971.

2. Minerals Yearbook: Bureau of Mines: 1969.

emissions was not available, but it was assumed to 0.5 percent, the same as shown in Table IX for open-hearth furnaces. Copper emissions to the atmosphere from blast furnaces totaled 1,070 tons.

$$\frac{95,472,000 \times 150 \times 0.005 (1 - 0.97)}{2,000} = 1,070$$

Open-Hearth Furnace - The overall operating cycle of the open-hearth furnace is about 10 hours. Even though fumes are discharged continuously at varying rates, average emission factors have been established for operation both with and without oxygen lancing. With oxygen lancing, the factor for uncontrolled emissions is 21 pounds of particulate per ton of steel. Without lancing, the factor is 8 pounds per ton. The degree of emission control is estimated at 40 percent, and the average emission factor (controlled) for all open-hearth furnace operations is 10.2 pounds of particulate per ton of steel produced [1].

The mean particle size of the dust is generally considered to be 0.5 micron [2] and a typical chemical analysis is

---

1. "Emissions, Effluents and Control Practices". Environmental Protection Agency. Study in Progress (unpublished) 1970.

2. Aberlow, E. B. "Modification to the Fontana Open Hearth Precipitators" JAPCA 7 May, 1957.

TABLE IX

SPECTROGRAPHIC ANALYSIS OF PARTICULATE DISCHARGE FROM AN OPEN-HEARTH FURNACE [1]/

Element	Approximate Amount* Percent
Fe	Remaining Amount
Zn	10 to 15
Na	1 to 2
K	1 to 2
Al	5
Ca	5
Cr	2
Ni	2
Pb	5
Si	5
Sn	1
Cu	0.5
Mn	0.5
Mg	0.1
Li	Trace
Ba	Trace
Sr	Trace
Ag	0.05
Mo	Trace
Ti	Trace
V	0.05

*These data are qualitative and require supplementary quantitative analysis for actual amounts.

1 "Air Pollution Engineering Manual" Public Health Service Publication No. 999 AP 40. p. 243. 1968.

shown in Table IX.

During 1969 the steel produced in open-hearth furnaces was 60,894,000 tons [1], and the copper content of the particulate matter emitted was about 0.5 percent. Copper emissions to the atmosphere totaled 1,550 tons.

$$\frac{60,894,000 \times 5.1 \times 0.005}{2,000} = 1,550$$

Basic Oxygen Furnace - During the one-hour operating cycle of the basic oxygen furnace, large quantities of gas and particulate are discharged to the atmosphere. The emission factor for this type of furnace has been estimated at 46 pounds of particulate per ton of steel (uncontrolled) [2], and the degree of emission control at 90 percent.

During 1969 the steel produced in basic oxygen furnaces was 60,236,000 tons [1], and the estimated copper content of the particulate emissions was 0.05 percent [3]. Copper emissions to the atmosphere totaled 70 tons.

---

1 - Minerals Yearbook. Bureau of Mines. 1969.

2 - "Air Pollutant Emission Factors". Environmental Protection Agency. Preliminary Document. Apr., 1971.

3 - Private communication.

$$\frac{60,236,000 \times 46 \times 0.0005}{2,000} (1 - 0.9) = 70$$

Electric Furnace - Electric arc furnaces are well suited to the production of alloy steels and are used extensively for that purpose. Emissions generated during operation consist of fume and dust emitted throughout the charging and refining operations. While charging, the top is open to receive the cold metal and the exposure of the cold charge to the high temperature inside the furnace results in the generation of large quantities of fume.

Particulate emissions from electric arc furnaces have been estimated with and without oxygen lancing at 11 pounds and 7 pounds per ton of steel, respectively [1]. The degree of control is estimated by the Contractor at 77 percent, and the average emission factor (uncontrolled) is 20 pounds of particulate per ton of steel produced [2].

During 1969 the steel produced in electric arc furnaces was 20,132,000 tons [3]. The copper content of the particulate

---

1 "Air Pollutant Emission Factors" Environmental Protection Agency Preliminary Document Apr., 1971.

2 Private communication.

3 Minerals Yearbook Bureau of Mines 1969.

is estimated at 0.16 percent (0.2 percent CuO as shown in Table X). Copper emissions to the atmosphere totaled 70 tons.

$$\frac{20,132,000 \times 20 \times 0.0016}{2,000} (1 - 0.77) = 70$$

TABLE X

TYPICAL EMISSIONS FROM AN ELECTRIC ARC FURNACE [1]/

Component	Weight %
Zinc Oxide (ZnO)	37
Iron Oxides	25
Lime (CaO)	6
Manganese Oxide (MnO)	4
Alumina (Al_2O_3)	3
Sulfur Trioxide (SO_3)	3
Silica (SiO_2)	2
Magnesium Oxide (MgO)	2
Copper Oxide (CuO)	0.2
Phosphorus Pentoxide (P_2O_5)	0.2

1- Coulter. R. S.; "Smoke, Dust, Fumes Closely Controlled in Electrode Furnaces": Iron Age; 173; Jan. 14, 1954.

FOUNDRIES

During this study spectrographic analyses of dust samples from foundries have been examined; they all indicate copper and numerous other elements are contained in the dust emitted to the atmosphere.

The cupola is the most used method for producing cast iron. The rate of particulate emissions from gray iron cupolas has been reported as 4 to 26 pounds per ton of process weight not including emissions from handling, charging, or other non-melting operations.

Based on information obtained from industry, the particulate emission factor is estimated at 22 pounds per ton of process weight, including melting and non-melting operations. The copper content of the particulate is about 0.03 percent [1]/ and the degree of emission control approximately 25 percent.

During 1969 the pig iron and scrap used by iron foundries totaled 18,594,000 tons [2]/. Copper emissions to the atmosphere due to the production of cast iron were about 50 tons.

---

1 - Private communication with industrial sources.

2 - Minerals Yearbook: Bureau of Mines: 1969.

INCINERATION

Numerous studies and tests have been conducted to determine the quantity of solid waste burned in incinerators and the particulate emissions that result. Reports from 3 sources contain information regarding copper emissions. One source shows that copper emissions are 4.2×10^{-2} pounds per ton of charge when burning refuse alone, and 5.7×10^{-2} pounds per ton of charge when burning a combination of refuse and sewage sludge [1]. The ratio of refuse to sludge during the tests was approximately 3.5 to 1.

Another source reports that household, commercial, and municipal wastes are over 250 million tons per year, and that approximately 8 percent of all municipal solid waste is burned in municipal incinerators [2].

The third source indicates that the burning of sewage and

---

1. Cross, F. L. Jr., Drago, R. J., and Francis, H. E. "Metal and Particulate Emissions from Incinerators Burning Sewage Sludge and Mixed Refuse". Proceedings of the National Incinerator Conference: Cincinnati, Ohio; 1970.

2. Black, R. J., Muhich, A. T., Klee, A. J., Hickman, H. L. Jr., and Vaughn, R. D. "The National Solid Wastes Survey, an Interim Report". (Presented at the 1968 Annual Meeting of the Institute of Solid Wastes of the American Public Works Association, Miami Beach, Florida; Oct. 24, 1968.)

sludge in the United States is at the rate of about 700,000 tons per year [1].

If we assume that all sewage sludge was burned with refuse at the ratio of 3.5 to 1, then 2.5 million tons of refuse were required for that purpose and 17.5 million tons were burned alone. The data reported indicate that copper emissions in the United States due to the burning of refuse and sewage sludge in municipal incinerators are nearly 460 tons per year.

$$\frac{17,500,000 \times 4.2 \times 10^{-2}}{2,000} + \frac{(2,500,000 + 700,000)\, 5.7 \times 10^{-2}}{2,000} = 460$$

1- Private communication with the Federal Water Pollution Control Authority.

UPDATING OF EMISSION ESTIMATES

The emissions and emission factors presented in this report are the result of calculations based principally on information obtained from industrial sources. They are specifically for the year 1969, but may be updated at any time when additional information is available. Either of the 2 methods described herein may be used for updating; however, the longer procedure, referred to as Method A, will yield results that are much more reliable.

The procedures to be followed with Method A are essentially the same as those used during the original study, which are described briefly as follows. More than 170 inquiries were sent to processing and reprocessing companies by mail or delivered during personal visits to plant sites. There was no reply from 52 companies and the answers from 39 others contained very little of the data requested. Some refused, but most of them claimed the information was not readily available. There are 79 companies that furnished all or a substantial part of the information requested, and this was the basis for emissions and emission factors set forth in this report.

All of the smelting and refining companies that produce

primary copper were requested to provide the essential data required for the study. Information was obtained concerning 9 of the 16 smelters and 7 of the 13 refineries. Based on the data obtained, emission factors were calculated and reported.

With respect to secondary copper, about 20 percent of the processing companies were contacted and data was obtained concerning nearly 25 percent of the production capacity. The reprocessing companies that provided information represented about 10 percent of the industry capacity.

Regardless of the method selected, the first step to be taken when updating the emission estimates is to obtain the latest issue of the Bureau of Mines Minerals Yearbook, Volume I-II, which is normally available within 16 or 18 months after the end of the calendar year (preprints of individual sections are usually available sooner). This publication shows the quantity of ore mined and the copper produced in the United States, as well as the quantities imported and exported. It also shows the amount of secondary copper produced and consumed, and the various forms in which it was used. This one publication contains all of the information that is required to update the material flow chart for copper.

When using Method A, the emission factors must be revised by contacting industry to determine the improvements in air pollution collection equipment efficiency and other processing changes affecting copper emissions. The revised emission factors may then be used with the production quantities obtained from the Minerals Yearbook or other referenced sources.

Method B is considerably shorter than Method A and less reliable. The only requirement is to revise the material flow chart according to the most recent published data and apply the emission factors shown in this report. In reality, this method is only a partial updating. There is no determination regarding improvements in air pollution control, a shift in production to more efficient plants, or any other considerations affecting emission factors. The advantage is the report can be updated within a very short length of time.

To update copper emissions from metallurgical processing and the iron and steel industry, it is preferable to use Method A. The remaining emissions shown in this report may be updated by Method B without introducing an appreciable error into the results.